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ENERGY DISSIPATION CHARACTERISTICS IN TISSUE FOR IONIZING  
RADIATION IN SPACE

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A Research Report with the title "Tissue Dosages from Alpha Particles and Heavy Nuclei in Solar Particle Beams" has been issued in August and is being distributed. The essential findings have been outlined already in the preceding Progress Report (No. 10).

The analysis in the just-mentioned study covers only the Z-spectrum from 1 (Protons) to 8 (Oxygen) because for solar particle beams the flux of nuclei  $Z \geq 10$  contributes only insignificantly to total exposure. For the galactic cosmic ray beam, quite differently, the heavier components are substantial contributors to the total dose. Especially at solar minimum when low energy particles are admitted to regions outside the magnetosphere the tissue dose in systems of low shielding (Extravehicular Activity, Lunar Excursion Module) can be expected to be influenced strongly by the heavy component and to show a strong dependence on shield thickness. Therefore, it appears of interest to extend the above mentioned analysis to nuclei up to  $Z = 26$  replacing the flare spectrum by the galactic cosmic ray spectrum.

Work along those lines is in progress. Unfortunately, information on some of the input data is poor. Good data exist for establishing the LET/energy and range/energy functions for heavy nuclei. Less well known are collision cross sections. This, however, does not seriously affect dose assessments in systems of low shielding. For such systems, a more severe limitation is imposed by the lack of data on the low rigidity section of the cosmic ray spectrum during solar minimum. This point has been discussed in detail in the Special Memorandum of May 20, 1965. Despite the just-mentioned shortcomings, it seems of interest to identify the limits of presently available information and how they affect assessments of tissue dosages. A large part of the computer code for this analysis containing the basic characteristics of heavy nuclei will be needed anyway in the future for evaluations of exposure as more accurate data on low rigidity cosmic rays from experiments during the 1964/65 period of the quiet sun will become available.

Near completion is the analysis of minimum and maximum type depth dose distributions for flare produced particle beams mentioned in the second paragraph of the preceding Progress Report (No. 10). The main objective of this study is not a determination of minimum or maximum flare doses as such, but a critical analysis of error propagation in the process of converting flux data presented in the form of rigidity spectra to tissue dosages. The results indicate that rigidity is a rather insensitive parameter as far as variation of depth dose gradients or dose fraction from components of different Z-numbers are concerned. The great simplification in the classification of flare events which physicists claim to have achieved with the introduction of the exponential rigidity spectrum finds no counterpart in a similar simplification of dosimetric characteristics. The fact that all flare spectra lie within a  $P_0$ -interval from 50 to 300 Mv (see preceding Progress Report No. 10) does not correspond to a similarly concise and general proposition for the depth dose patterns. As  $P_0$  changes from 50 to 300 Mv, i.e., by a factor of 6, depth dose gradients and depth doses themselves at given depths vary in strongly nonlinear fashion and in a greatly different way for different Z-components by factors of more

than  $10^9$ . The pertinent relationships are derived and presented in detail in the study. They show that especially for systems of low shielding, data presented in terms of rigidity leave a very wide margin of indeterminacy for tissue dosages. Errors or uncertainties of a few per cent in particle rigidity appear greatly magnified in the corresponding dosimetric quantities. This holds equally true for solar particle beams as well as for low rigidity galactic cosmic rays. A Research Report presenting the results of this study should be completed by October.